Health Consultation

Perfluorooctane Sulfonate (PFOS) in Fish

FORMER WURTSMITH AIR FORCE BASE
OSCODA, IOSCO COUNTY, MICHIGAN

EPA FACILITY ID: MI5570024278

Prepared by
Michigan Department of Health and Human Services

FEBRUARY 14, 2017

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Agency for Toxic Substances and Disease Registry (ATSDR)

Foreword

The Michigan Department of Health and Human Services (MDHHS) conducted this evaluation for the federal Agency for Toxic Substances and Disease Registry (ATSDR) under a cooperative agreement. ATSDR conducts public health activities (assessments/consultations, advisories, education) at sites of environmental contamination. The purpose of this document is to identify potentially harmful exposures and recommend actions that would minimize those exposures. This is not a regulatory document and does not evaluate or confirm compliance with laws. This is a publicly available document and is provided to the appropriate regulatory agencies for their consideration.

The following steps are necessary to conduct public health assessments/consultations:

- Evaluating exposure: MDHHS toxicologists begin by reviewing available information about environmental conditions at the site: how much contamination is present, where it is found on the site, and how people might be exposed to it. This process requires the measurement of chemicals in air, water, soil, or animals. Usually, MDHHS does not collect its own environmental sampling data. We rely on information provided by the Michigan Department of Environmental Quality (MDEQ), U.S. Environmental Protection Agency (EPA), and other government agencies, businesses, and the general public.

- Evaluating health effects: If there is evidence that people are being exposed – or could be exposed – to hazardous substances, MDHHS toxicologists then determine whether that exposure could be harmful to human health, using existing scientific information. The report focuses on public health – the health impact on the community as a whole.

- Developing recommendations: In its report, MDHHS outlines conclusions regarding any potential health threat posed by a site, and offers recommendations for reducing or eliminating human exposure to contaminants. If there is an immediate health threat, MDHHS will issue a public health advisory warning people of the danger, and will work with the appropriate agencies to resolve the problem.

- Soliciting community input: The evaluation process is interactive. MDHHS solicits and considers information from various government agencies, parties responsible for the site, and the community. If you have any questions or comments about this report, we encourage you to contact us.

  Please write to: Toxicology and Response Section
  Division of Environmental Health
  Michigan Department of Health and Human Services
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  For more information, please visit:
  www.michigan.gov/envirohealth

Table of Contents

List of Tables

List of Figures

List of Appendices

Acronyms and Abbreviations

µg	microgram
ADHD	Attention Deficit Hyperactivity Disorder
AFFF	aqueous film-forming foam
ATSDR	Agency for Toxic Substances and Disease Registry
AUC	area under the curve
CASRN	Chemical Abstract Service Registry Number
DHD#2	District Health Department #2
EPA	U.S. Environmental Protection Agency
FCSV	Fish Consumption Screening Value
FOSAA	perfluorooctanesulfonamidoacetic acid
HDL	high-density lipoprotein
kg	kilogram
L	liter
LDL	low-density lipoprotein
MDHHS	Michigan Department of Health and Human Services
MDEQ	Michigan Department of Environmental Quality
MDH	Minnesota Department of Health
MDNR	Michigan Department of Natural Resources
MFCAP	Michigan Fish Consumption Advisory Program
mg	milligram
MRL	Minimal Risk Level
NC	not calculated
ND	not detected
NHANES	National Health and Nutrition Examination Survey
NOAEL	No Observed Adverse Effect Level
PCB	polychlorinated biphenyl
PFAS	per- and polyfluorinated alkyl substance(s)
PFBA	perfluorobutanoic acid
PFBS	perfluorobutane sulfonate
PFC	perfluorinated chemical
PFDA	perfluorodecanoic acid
PFDS	perfluorodecane sulfonate
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHpS	perfluoroheptane sulfonate
PFHxA	perfluorohexanoic acid
PFHxDA	perfluorohexadecanoic acid
PFHxS	perfluorohexane sulfonate
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFODA	perfluorooctanedecanoic acid
PFOS	perfluorooctane sulfonate
PFOSA	perfluorooctane sulfonamide
PFPA	perfluoropentanoic acid

PFTeA	perfluorotetradecanoic acid
PFTriA	perfluorotridecanoic acid
PFUnA	perfluoroundecanoic acid
ppb	parts per billion
ppt	parts per trillion
RfD	Reference Dose
T3	triiodothyronine
T4	thyroxine
TSH	thyroid-stimulating hormone
UCL	Upper Confidence Limit
USAF	U.S. Air Force
USFS	U.S. Forest Service
WAFB	former Wurtsmith Air Force Base
YMCA	Young Men's Christian Association

Purpose and Health Issues

This document discusses the perfluorinated chemical (PFC) contamination at the former Wurtsmith Air Force Base (WAFB) in Oscoda, Michigan, with a focus on perfluorooctane sulfonate (PFOS) levels in fish sampled from nearby waterbodies.[1] The document describes, in brief, the Michigan Department of Health and Human Services (MDHHS) public health hazard determination and resulting emergency Do Not Eat fish consumption advisory due to the elevated PFOS levels in the fish. The document also discusses MDHHS health education outreach actions conducted to-date. Lastly, the document lists conclusions and recommendations to address the continued release of PFCs into the waters surrounding WAFB.

Although various PFCs are present in the environment, including in the fish, around WAFB, the primary PFC of concern is PFOS because:

- PFOS was detected in nearly all fish sampled from area waterbodies, with the concentration of PFOS being at least 90 percent of the total PFC concentration in the vast majority of the samples;
- PFOS has been the most commonly detected PFC in biota (fish and other wildlife) sampled from the Great Lakes region (Kannan et al. 2005, Ye et al 2008, Delinksy et al. 2009);
- PFOS usually has the highest concentration compared to other PFCs (Ye et al. 2008, Delinsky et al. 2010); and
- PFOS bioaccumulates (builds up in the food chain; EPA 2009).

Therefore, this document discusses PFOS, but not other PFC, levels in fish near the WAFB.

Human exposure to PFCs by different pathways and to other environmental contaminants from WAFB may exist in this area. These issues will be the focus of future documents, as needed.

[1] The public-comment version of this document was issued at the time that the term "PFC" was still in use. "PFC" has since been replaced in the scientific community with "per- and polyfluorinated alkyl substaces," or "PFAS." For purposes of simplicity, this document shall continue using "PFC," but future documents shall refer to the chemicals as "PFAS."

Summary

In 2011, the Michigan Department of Environmental Quality (MDEQ) sampled fish from the upper and lower ponds in Clark's Marsh, a wetland located between the former Wurtsmith Air Force Base (WAFB) and the lower Au Sable River in Oscoda, Michigan. The fish filets were analyzed for perfluorinated chemicals (PFCs). The MDEQ then requested that the Michigan Department of Health and Human Services (MDHHS) evaluate the results, to determine if public health action was warranted. MDHHS concluded that people should not eat any fish from the ponds or any non-migratory fish from the lower Au Sable River, due to high levels of perfluorooctane sulfonate (PFOS) in the edible fish tissue and the uncontrolled release of PFCs from WAFB to the environment. This was considered a public health hazard, and an emergency Do Not Eat fish consumption advisory was issued immediately.

Since establishing the emergency fish consumption advisory, MDHHS has collected additional fish data, reviewed the still-emerging scientific literature on PFCs, updated the fish consumption guidelines, and conducted health education and outreach in the area. The area has about 10,000 residents and relies heavily on tourism, especially fishing in the Au Sable River. Addressing the PFC contamination entering the waters near WAFB is essential to relaxing or removing the fish consumption advisory.

MDHHS has reached the following conclusion about the PFOS contamination at and near WAFB:

Levels of PFOS found in fish consumed regularly from Clark's Marsh, Allen Lake, and portions of the Au Sable River could harm people's health.

Basis: There are multiple locations at WAFB with PFC contamination, particularly at the FT-02 fire-training area. Some of this contamination has impacted fish in local waterbodies. The primary PFC of concern in the fish is PFOS, with fish tissue concentrations exceeding MDHHS screening values, including Do Not Eat levels.

Completed Actions:

- ✓ MDHHS has issued a Do Not Eat fish consumption advisory for certain fish in local waterbodies. The Do Not Eat guidelines pertain to all fish in the Clark's Marsh ponds and Allen Lake but only to resident fish in the lower Au Sable River (those fish living in the river year-round). Migratory fish in the river (walleye, rainbow trout/steelhead, and salmon) are covered by Eat Safe Fish guidelines for Lake Huron. Fish from area waterbodies may have waterbody-specific guidelines due to other chemicals or are covered by the Statewide Safe Fish Guidelines (for when a waterbody or fish species is not listed). "Eat Safe Fish" guides, showing the fish-consumption guidelines, are available at www.michigan.gov/eatsafefish.
- ✓ The agency also has conducted public meetings and provided Eat Safe Fish signs and brochures specific to the area. Meetings were conducted in 2013, 2014, and 2015. Signs were posted at Clark's Marsh and Allen Lake in 2013 and along the lower Au Sable River in 2013 and 2014. Brochures were distributed locally and posted to MDHHS's website in 2014 and 2015.

Next Steps:

- Ongoing environmental investigations by the U.S. Air Force (USAF) will determine if and to what extent other areas of PFC contamination at the base are impacting local waterbodies, including the lower Au Sable River and Van Etten Lake.
- The USAF has installed a pump-and-treat system near the fire-training site (the main area of contamination) to contain PFC-contaminated groundwater in that area. The system became operational in April 2015.
- Further site assessment is necessary to determine if other PFC release areas at the base are impacting groundwater and surface waters.
- The USAF will collect more fish to establish a pre-remediation baseline and will confer with MDHHS regarding future fish sampling. MDEQ may choose to sample fish in the area at any time, to monitor for PFCs or other contaminants (e.g., mercury, polychlorinated biphenyls [PCBs]).

Limitations of these findings:

- PFC exposure and toxicity information continues to be published in the scientific literature, which may result in regulatory and public health agencies adjusting their efforts as new information becomes known.
- In 2016, the EPA Office of Water developed Reference Doses for two PFCs – perfluorooctanoic acid (PFOA) and PFOS – from which the agency derived lifetime health advisory levels in drinking water (EPA 2016). The federal Agency for Toxic Substances and Disease Registry (ATSDR; 2015) has released a Draft for Public Comment Toxicological Profile for Perfluoroalkyls. MDEQ (2014) has finalized an evaluation for surface water, and MDHHS (2014) has finalized an evaluation for fish consumption.
- The PFCs source(s) on the former WAFB have not been fully evaluated, which limits predictions about the environmental fate of the contamination both on and off the former base.

Background

WAFB began operations in 1923, under the name of Camp Skeel, and was officially named the Wurtsmith Air Force Base in 1953. The base is located in Oscoda, Iosco County, Michigan (Figure 1). WAFB closed in 1993 and is gradually being turned over to the Oscoda Airport Authority for reuse as an industrial park and airfield (Civilian Exposure 2016). The 5,221-acre site is bounded by Van Etten Lake to the north and east, Oscoda and Au Sable Townships to the east and south, the Huron National Forest (including wetlands associated with the Au Sable River) to the south, and the Au Sable State Forest to the north and west. Lake Huron is less than one mile east of the site (ATSDR 2001).

The primary industry of Oscoda Township (north of the mouth of the Au Sable River) and Au Sable Township (south of the river's mouth) is tourism.[2] The Au Sable River and other local waterbodies, Lake Huron, and state and national forests provide many opportunities for recreation. Activities include swimming, boating, camping, birding, hunting, and fishing.

PFC Contamination

Over the years, various formulations of aqueous film-forming foams (AFFF) have been developed to assist the military, commercial aviation, and refineries in fighting flammable-liquid fires ("Class B" fires). The film that is formed seals in vapors from the fuel, which would otherwise ignite, and seals out oxygen, which is needed for the fire to burn. The foam is much more effective than using water for fire-control efforts.[3]

The USAF trains for and responds to aircraft accidents (e.g., crashes, hangar fires), to protect life and property. According to an Air Force toxicologist, PFOS-based AFFF use at air force bases started in 1970. By 2000, the USAF was no longer releasing PFOS-based AFFF at fire training sites at its bases, however the military has set aside the product for emergency use (J. Anderson, USAF Emerging Issues Program, personal communication, 2012).

There are two former fire-training (FT) sites at WAFB. "FT-01," near the northeast end of the runway (not shown), was used between 1951 and 1958 (ATSDR 2001). Considering when PFOS-based AFFF was reported to have begun use (1970), it is unlikely that particular formulation of fire-fighting foam was used in this area.[4] "FT-02" is located at the southwest end of the base, near Clark's Marsh which is north of the Au Sable River (Figures 2 and 3). This fire-training area was used from the 1950s to the early 1990s (ATSDR 2001, Moody et al. 2003). Data collected by MDEQ and others have shown that PFOS and other perfluorinated chemicals have contaminated this area, leached through the sandy soil into the groundwater, and migrated into the surface water and sediments in the ponds at Clark's Marsh. See Appendix A for the range of PFOS concentrations found in groundwater and surface waters near WAFB.

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[2] See www.oscodatwp.com and www.ausabletownship.net.

[3] See http://www.nrl.navy.mil/accomplishments/materials/aqueous-film-foam/.

[4] The Michigan Department of Environmental Quality (MDEQ) reports that PFCs have been detected in environmental samples near the FT-01 area, but the source has not yet been identified (R. Delaney, MDEQ, personal communication, 2014).

Figure 1: Former Wurtsmith Air Force Base and Vicinity, Oscoda (Iosco County), Michigan.

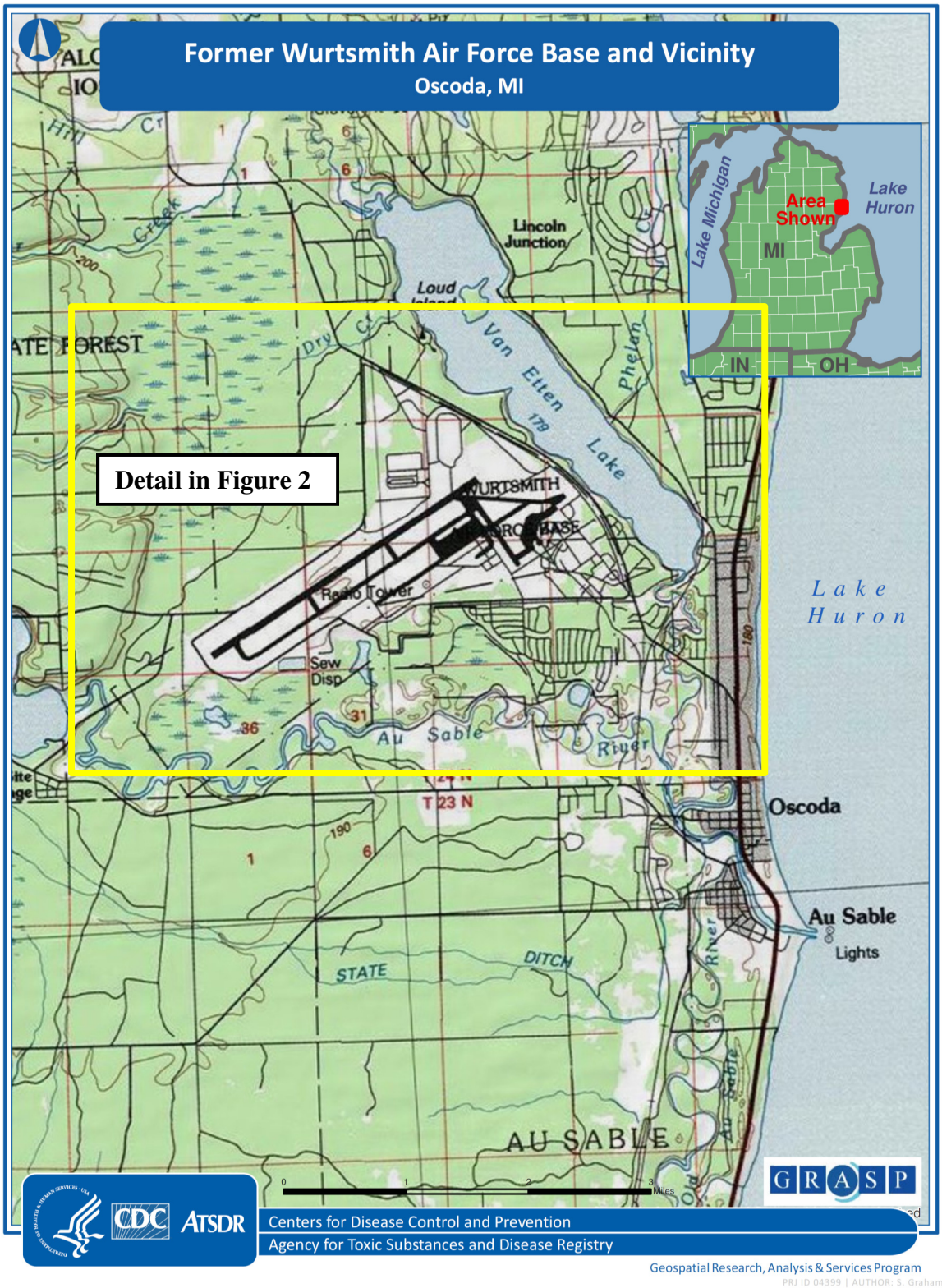
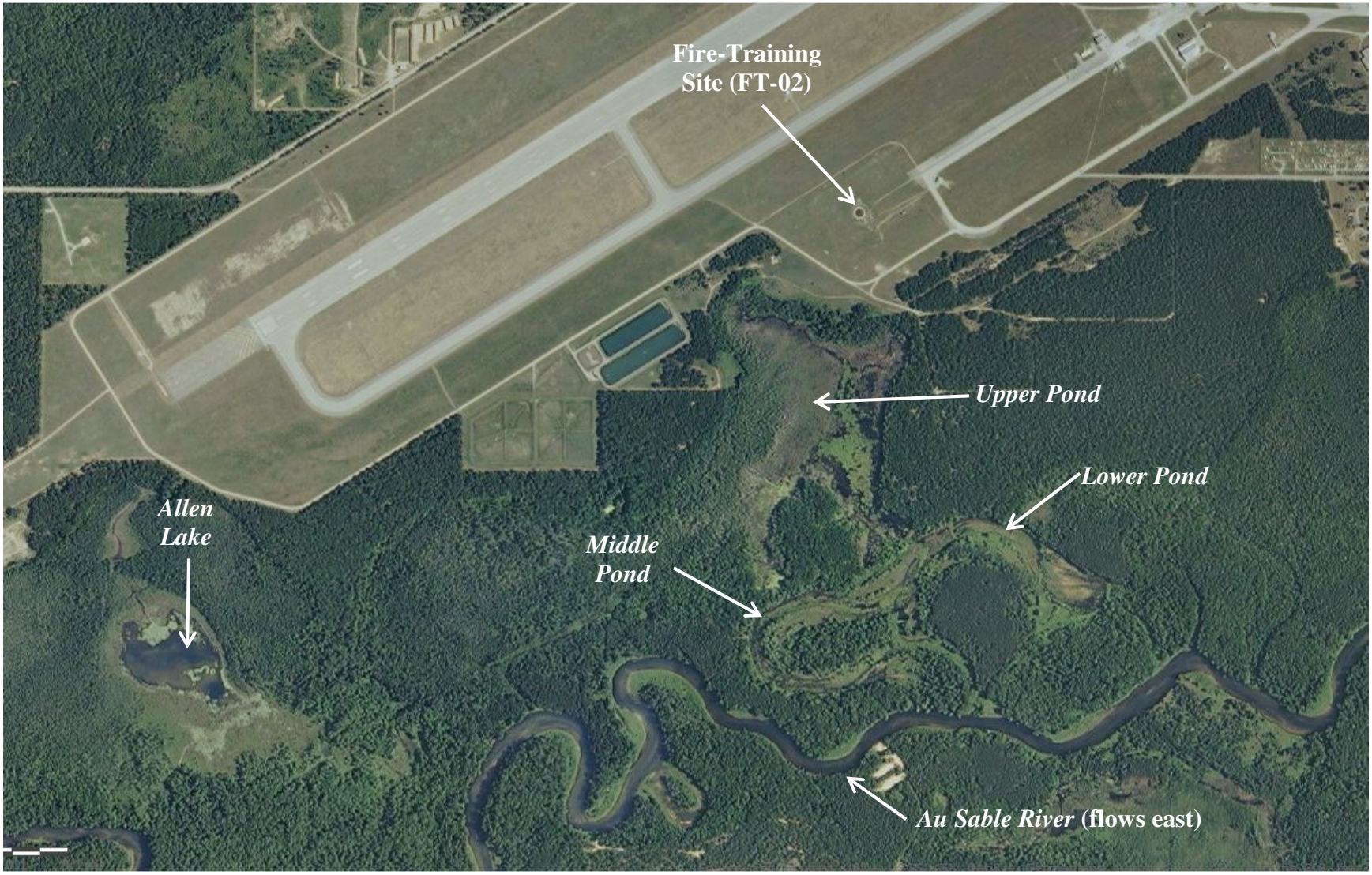


Figure 2. Areas of interest at or near the former Wurtsmith Air Force Base in Oscoda (Iosco County), Michigan.

Figure 3. Ponds in Clark's Marsh and other features at or near the former Wurtsmith Air Force Base, Oscoda (Iosco County), Michigan.



The ponds in Clark's Marsh originally were formed by beaver dams, however the dams were replaced in 2006 with engineered earthen dikes that have water control structures and emergency spillways (MDEQ 2006c). Therefore, water can pass from the ponds to the lower Au Sable River but fish theoretically cannot.[5] There are three ponds: an upper pond, which is closest to FT-02; a middle pond, which receives water from the upper pond; and a lower pond, which receives water from the middle pond and then discharges via a stream to the lower Au Sable River (Figure 3).

Studies have found that PFC contamination can enter fishable waterbodies and bioaccumulate in fish (Moody et al. 2002, Sinclair et al. 2006, Furdui et al. 2007, Delinsky et al. 2010). In 2011, MDEQ sampled fish from the upper and lower ponds in Clark's Marsh and submitted them for PFC analysis. MDHHS evaluated the data and compared them to provisional screening levels calculated by the department's Division of Environmental Health.[6] The concentrations of PFOS detected in filets of the fish from the upper pond exceeded the provisional Do Not Eat level by up to five times. PFOS concentrations in fish taken from the lower pond did not exceed the provisional Do Not Eat level but still were substantially elevated.

MDHHS immediately issued an emergency public health advisory, recommending that people not eat any fish from Clark's Marsh, based on the elevated PFOS levels and the knowledge that there was an uncontrolled source of PFOS to the marsh. Because the Clark's Marsh ponds drain to the lower Au Sable River, and because uncertainty exists about how PFOS levels in fish may change over time and space or vary by species, MDHHS extended the Do Not Eat advisory to include fish from the lower Au Sable River, between Foote Dam and the mouth of the river (MDHHS 2012a, b).

After the initial advisory was issued, MDHHS, in collaboration with MDEQ, accomplished the following tasks to evaluate further the PFC contamination in fish from waterbodies near WAFB:

- ✓ Collected and analyzed additional fish
- ✓ Evaluated fish filet PFC results
- ✓ Reviewed existing PFC data in Lake Huron fish
- ✓ Held additional discussions with MDEQ on the environmental fate of the WAFB PFC contamination.

Based on this further evaluation, MDHHS made these updates to the fish consumption advisories by January 2013:

- ➢ Continued the Do Not Eat guideline for any fish from Clark's Marsh
- ➢ Added a Do Not Eat guideline for fish from Allen Lake, based on the lake's proximity to the fire-training area (Figures 2 and 3) and a surface water sample from the stream draining the lake having detectable PFOS levels

[5] The U.S Forest Service, who manages the Clark's Marsh ponds, indicates that fish might escape from an upstream pond to a downstream pond when water control boards are adjusted to regulate water levels in the ponds (which is rarely done) or if water overflows through the emergency spillway (which also occurs infrequently).

[6] As discussed later in this document, MDHHS issued final screening levels for PFOS in fish in 2014. Therefore, the provisional screening levels are not discussed in detail here. For information on the provisional screening levels, see MDHHS 2012b.

- Continued the Do Not Eat guideline on resident fish caught from the lower Au Sable River (those fish living in the river year-round)
- Removed the Do Not Eat guideline on Lake Huron migratory fish caught in the lower Au Sable River and advised consumers of Lake Huron fish, which have other chemical contaminants, to refer to MDHHS's "Eat Safe Fish" Guide (www.michigan.gov/eatsafefish)
- Determined that fish from Van Etten Lake had low levels of PFCs, including PFOS, and advised consumers of these fish to refer to MDHHS's "Eat Safe Fish" Guide

MDHHS has conducted several community outreach and health education activities in the area. In January 2013, MDHHS held a public open house and community meeting in Oscoda to explain the Do Not Eat advisory and the updates noted above. MDHHS provided a fact sheet regarding the advisory, along with giving an informational presentation, at the community meeting.[7] The USAF discussed their plans to address the PFC contamination.[8] Staff from other agencies (MDEQ, Michigan Department of Natural Resources [MDNR], District Health Department #2 [DHD#2], U.S. Forest Service [USFS]) and local government officials were also at the meeting.

In February 2013, MDHHS met with several stakeholders, including an outdoor sports business and a member of the Chippewa Nation of the Great Lakes tribe, to receive input on the design of fish advisory signs that would be posted in the area. The signs were finalized later in the year and posted at Clark's Marsh and Allen Lake in May 2013, and along the lower Au Sable River in June 2013. See Appendix B to view the signs.

In February 2014, MDHHS held another public open house and community meeting in Oscoda to update the community on public health activities.[9] MDHHS provided a data sheet showing the PFOS levels in the fish that were tested and a "Frequently Asked Questions" fact sheet about PFOS.[10] MDHHS also encouraged community input for an area-specific "Eat Safe Fish" brochure that the agency was developing.[11] Additionally, MDHHS reported that about half of the signs that had been posted along the river in 2013 had been removed by unknown parties. MDHHS requested input from the community on ways to make the signs more accepted (see the revised sign, posted in 2014, in Appendix B). The USAF provided an update on the status of

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[7] Available at http://www.michigan.gov/documents/mdch/Wurtsmith_Fact_Sheet_-_final_406532_7.pdf and http://www.michigan.gov/documents/mdch/Wurtsmith_Air_Force_Base_Public_Mtg_mdch__012413_compressed_410340_7.pdf.

[8] Available at http://www.michigan.gov/documents/mdch/Wurtsmith_Air_Force_Base_Public_Mtg_AFCEC_-_012413_410341_7.pdf.

[9] MDHHS/MDEQ slides available at http://www.michigan.gov/documents/mdch/Former_Wurtsmith_Air_Force_Base__Activity_Update_PFCs_compressed_451787_7.pdf.

[10] An April 2015 update to the fish data sheet is available at http://www.michigan.gov/documents/mdch/fish_data_handout_449030_7.pdf. The "Frequently Asked Questions" fact sheet about PFOS is available at http://www.michigan.gov/documents/mdch/PFOS_FAQ_fact_sheet_021114_449031_7.pdf.

[11] The brochure was finalized and distributed in 2014 but was updated in 2015. The 2014 version was removed from the MDHHS website and replaced with the 2015 version at: http://www.michigan.gov/documents/mdch/Wurtsmith_brochure_3.2014_451836_7.pdf.

investigative and remedial efforts. Other agencies (MDEQ, MDNR, DHD#2, USFS, and the Alcona/Iosco Conservation District) and local government officials were also at the meeting.

In September 2014, MDHHS completed a technical support document for PFCs, including a toxicological assessment of PFOS, for the Michigan Fish Consumption Advisory Program (MFCAP; MDHHS 2014). The document included final screening values for PFOS in fish (see Appendix C).

In April 2015, MDHHS held another public open house and community meeting in Oscoda to provide an update on activities.[12] The USAF presented information on the pump-and-treat system recently installed at the FT-02 area and discussed plans for further work at the site. MDEQ, DHD#2, USFS, and local officials also attended the meeting.

In March 2016, MDHHS released a draft version of this health consultation document for public review and comment. No public comments were received.

Discussion

Environmental Contamination

The following PFCs were analyzed for in fish tissue samples from waterbodies near WAFB (those PFCs listed in **bold** print were detected in the fish tissue samples):

Perfluorobutane sulfonate (PFBS)	**Perfluorononanoic acid (PFNA)**
Perfluorobutanoic acid (PFBA)	**Perfluorooctane sulfonamide (PFOSA)**
Perfluorodecanoic acid (PFDA)	**Perfluorooctane sulfonate (PFOS)**
Perfluorododecanoic acid (PFDoA)	**Perfluorooctanoic acid (PFOA)**
Perfluoroheptanoic acid (PFHpA)	Perfluoropentanoic acid (PFPA)
Perfluorohexanoic acid (PFHxA)	**Perfluorotridecanoic acid (PFTriA)**
Perfluorohexane sulfonate (PFHxS)	**Perfluoroundecanoic acid (PFUnA)**

PFOS was detected in nearly all fish sampled near WAFB, with the concentration of PFOS being at least 90 percent of the total PFC concentration in the vast majority of the samples. The PFOS levels for all fish sampled from waterbodies near WAFB are shown in Appendix D.

The Michigan Fish Consumption Advisory Program (MFCAP) only uses analytical data from the MDHHS Analytical Chemistry Laboratory or data that have been validated by the MDHHS lab. Table 1 shows the data for resident (non-migratory) fish from area waterbodies that were evaluated for the MFCAP.

In 2014, MDHHS finalized Fish Consumption Screening Values (FCSVs) for PFOS, as shown in Table 2. The basis for the PFOS screening values is discussed in the *Toxicological Evaluation* section of this document.

[12] MDHHS slides available at http://www.michigan.gov/documents/mdch/Former_Wurtsmith_Air_Force_Base__Activity_Update_042915_488430_7.pdf.

Table 1. Minimum, maximum, and 95 percent upper confidence limit (95% UCL) of the mean perfluorooctane sulfonate (PFOS) wet weight concentrations (in parts per billion [ppb]) in fish filets collected for the Michigan Fish Consumption Advisory Program from Clark's Marsh, the lower Au Sable River, and Van Etten Lake in Oscoda (Iosco County), Michigan.[1,2] Samples collected between 2010 and 2012.

Waterbody	Type of Fish	No. Samples	Min – Max (parts per billion [ppb])	95% UCL (ppb)
Clark's Marsh	Bluegill/Pumpkinseed	19	334 - 9,580	5,619
Lower Au Sable River	Bluegill/Pumpkinseed	4	35 - 2,956	NC[3]
	Rock Bass	8	7 - 49	37
	Smallmouth Bass	15	19 - 424	157
	White Sucker	10	6 - 143	60
Van Etten Lake	Pumpkinseed	10	5.6 - 13	10
	Rock Bass	10	4.8 - 18.3	14
	Walleye	10	3.9 - 45.7	33
	White Sucker	10	0.7 - 28.2	19

[1] Only data for resident (non-migratory) fish from these waterbodies are shown. Appendix D shows PFOS levels for all fish sampled from the area.

[2] People deciding whether to eat fish from the area should not base their decision only on PFOS levels. The "Eat Safe Fish" Guides (www.michigan.gov/eatsafefish) list the chemicals of concern for each specific guideline.

[3] NC – not calculated in the Michigan Fish Consumption Advisory Program due to too few samples.

Table 2. State of Michigan Fish Consumption Screening Value (FCSV) ranges for perfluorooctane sulfonate (PFOS; MDHHS 2015).

Meal Category	FCSV Ranges
meals per month[1,2]	*parts per billion (ppb)*
16	≤ 9
12	>9 to 13
8	>13 to 19
4	>19 to 38
2	>38 to 75
1	>75 to 150
6 meals per year	>150 to 300
Do Not Eat	>300

[1] Units are in meals per month unless otherwise stated.

[2] A "meal" is described as a "MI Serving," the weight of which changes with body weight. For example, a MI Serving is 8 ounces for an 80 kilogram (kg) person, 4 ounces for a 40 kg person, and 2 ounces for a 20 kg person (MDHHS 2015).

When compared to the 2014 FCSVs for PFOS, all Clark's Marsh fish filets exceeded the Do Not Eat meal category by as much as 30 times, with the 95 percent upper confidence limit (95% UCL) exceeding it by almost 20 times. (The 95% UCL represents a statistical upper level of the true mean for a reasonable maximum exposure estimate.) The filets from fish sampled in the lower Au Sable River shown in Table 1 varied greatly in PFOS content. The range of PFOS concentrations in fish from Van Etten Lake was much smaller.

For the fish shown in Table 1 that did not exceed the Do Not Eat FCSV for PFOS, MDHHS used best professional judgment and made management decisions, as described in the *Fish Consumption Guideline Determinations* section, to set meal categories. Note that area waterbodies may have fish consumption guidelines that are based on other chemicals, such as mercury and PCBs. The "Eat Safe Fish" Guides (available at www.michigan.gov/eatsafefish) show the chemical that is causing the consumption guideline for fish species sampled from various waterbodies.

Exposure Pathways Analysis

To determine whether persons are, have been, or are likely to be exposed to contaminants, MDHHS evaluates the environmental and human components that could lead to human exposure. An exposure pathway contains five elements:

- a source of contamination
- contaminant transport through an environmental medium
- a point of exposure
- a route of human exposure
- a receptor population

An exposure pathway is considered "complete" if there is evidence, or a high probability, that all five of these elements are, have been, or will be present at a site. It is considered an "incomplete" pathway if there is no evidence that at least one of the elements is, has been, or will be present.

Note that a completed pathway does *not* mean that an exposure is substantial or that harm will result. Further evaluation of the exposure dose and the chemical's toxicity is necessary before public health conclusions can be made.

Table 3 shows the fish-consumption pathway for PFOS exposure at or near WAFB and whether human exposure in the past, present, or future is likely.

Table 3. Fish-consumption exposure pathway analysis for perfluorooctane sulfonate (PFOS) contamination at and near the former Wurtsmith Air Force Base (WAFB), Oscoda (Iosco County), Michigan.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Time Frame	Exposure Likelihood?
Areas at the WAFB where releases of PFOS-containing fire-fighting foam occurred	Soil leaching to groundwater, discharging into area surface waters	Locally caught fish	Ingestion	Local residents and visitors	Past	Complete
					Present	Potential
					Future	Potential

Reportedly, use of PFOS-based AFFF at the base began in 1970. Therefore, the earliest that PFCs from the base could have entered area groundwater, surface water, and ultimately fish would have been in the early 1970s. PFCs were detected in groundwater samples taken in 1998 and 1999 (Moody et al. 2003),[13] but fish from the area were not tested for PFCs until 2011. Before the U.S. Army Corps of Engineers replaced the beaver dams at Clark's Marsh in 2006 with earthen dikes, MDEQ had conducted a surface water quality assessment of the wetland. Field staff noted populations of yellow perch, bluegill, largemouth bass, and white sucker at the ponds in the marsh. Staff also reported evidence of people using the ponds for fishing, noting discarded fishing equipment along the banks (MDEQ 2006b). Therefore, past human exposure to PFC-contaminated fish has likely occurred.

Metal signs informing users about the advisory (Appendix B) were posted at multiple locations around those waterbodies in the spring and summer of 2013, however about half the signs were missing by the end of that year. New signs with updated messaging have since been posted, and MDHHS has developed an area-specific "Eat Safe Fish" brochure,[14] among other outreach efforts.[15] The efficacy of these outreach efforts is not known. Therefore, there is potential for current human exposure to PFC-contaminated fish in the area. Until the source of PFC contamination is controlled and PFOS levels in local fish decrease, the potential for human exposure will remain.

Toxicological Evaluation

General Information on PFCs

PFCs can be found in over 200 industrial and commercial applications. The desirable properties of PFCs – fire resistance and oil, stain, grease, and water repellency – have allowed the chemicals to be used in fire-fighting foams, nonstick cookware, waterproof yet breathable apparel, as well as many manufacturing and industrial processes (Lau et al. 2007, EPA 2009).

[13] There are no published PFC groundwater data for WAFB before Moody et al. (2003).
[14] Available at http://www.michigan.gov/documents/mdch/Wurtsmith_brochure_3.2014_451836_7.pdf. The brochure has been made available at area businesses and offices, for both the community members and visitors.
[15] See http://www.michigan.gov/wurtsmith.

PFCs contain a carbon "backbone" in which each carbon is fully fluorinated (i.e., perfluorinated). Table 4 presents carbon-chain length, abbreviations, chemical formulas, names and Chemical Abstract Service Registry Number (CASRN, or CAS Number)[16] of select PFCs. The carbon-fluorine bond is extremely strong, increasing in strength as the number of fluorines in the molecule increases. PFCs must be incinerated at greater than 1,100° Celsius (2,000° Fahrenheit) to break apart the carbon-fluorine bond (Seow 2013).

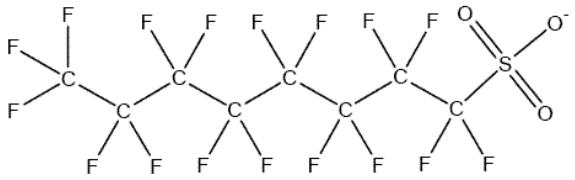
Table 4. Select perfluorinated chemicals, including Chemical Abstract Service Registry Number (CAS Number).

Carbons	Abbreviation	Formula	Name	CAS Number
C4	PFBA	$C_4HF_7O_2$	perfluorobutanoic acid	375-22-4
C4	PFBS	$C_4HF_9O_3S$	perfluorobutane sulfonate	375-73-5
C5	PFPA	$C_5HF_9O_2$	perfluoropentanoic acid	2706-90-3
C6	PFHxA	$C_6HF_{11}O_2$	perfluorohexanoic acid	307-24-4
C6	PFHxS	$C_6HF_{13}O_3S$	perfluorohexane sulfonate	355-46-4
C7	PFHpA	$C_7HF_{13}O_2$	perfluoroheptanoic acid	375-85-9
C8	PFOA	$C_8HF_{15}O_2$	perfluorooctanoic acid	335-67-1
C8	PFOS	$C_8HF_{17}O_3S$	perfluorooctane sulfonate	1763-23-1
C8	PFOSA	$C_8H_2F_{17}NO_2S$	perfluorooctane sulfonamide	754-91-6
C9	PFNA	$C_9HF_{17}O_2$	perfluorononanoic acid	375-95-1
C10	PFDA	$C_{10}HF_{19}O_2$	perfluorodecanoic acid	335-76-2
C11	PFUnA	$C_{11}HF_{21}O_2$	perfluoroundecanoic acid	2058-94-8
C12	PFDoA	$C_{12}HF_{23}O_2$	perfluorododecanoic acid	307-55-1
C13	PFTriA	$C_{13}HF_{25}O_2$	perfluorotridecanoic acid	72629-94-8

PFCs with eight or more carbons are considered to be more bioaccumulative (i.e., they build up in the food chain) than those with seven or fewer carbons (Lindstrom et al. 2011); Martin et al. (2003) determined that sulfonate PFCs bioconcentrated to a greater extent than carboxylate PFCs with the same number of carbons. PFOS contains eight carbons in its "backbone." Once PFOS enters the environment, it does not undergo chemical, microbial, or photolytic degradation or breakdown (OECD 2002). The chemical structure of PFOS is shown in Figure 4.

[16] The Chemical Abstract Service Registry Number (CASRN or CAS Number) for a chemical is a unique identifier. Since a single chemical may have many synonyms and variations of its name, it is important that scientists have a standardized way of clearly identifying a chemical. The CASRN for PFOS is 1763-23-1. PFOS can exist as a potassium (CASRN 2795-39-3), ammonium (CASRN 29081-56-9), or other salt. It can also be yielded from a larger, related polymer that undergoes environmental degradation (EFSA 2008).

Figure 4. Chemical structure of perfluorooctane sulfonate (PFOS).



In 2002, 3M, the primary manufacturer of PFOS in the U.S., voluntarily decided to cease global production of PFOS and perfluorooctanoic acid (PFOA) by 2002, because of the chemicals' environmental impacts. The EPA then issued several Significant New Use Rules restricting the new manufacture and import of perfluoroalkyl sulfonates (a sub-category of PFCs of which PFOS is a part). While some uses of PFOS remain unaffected (including in hydraulic fluids, semiconductors, and electroplating), other uses have been phased out or require EPA notification and review before implementation.[17] Fire-fighting foam manufacturers have been transitioning to shorter-chain (six-carbon) telomer-based surfactants, to reduce the impact on the environment, and investigating fluorine-free formulations for several years (Industrial Fire Journal 2013, Seow 2013).

PFCs bind to proteins in liver and blood rather than accumulating in the fat (MDHHS 2014). In general, the highest concentrations in wildlife have been found in the livers of fish-eating animals close to industrialized areas (EPA 2009). PFCs have been detected in human blood, breast milk, liver, umbilical cord blood, and seminal plasma (CDC 2009, EPA 2009).

Toxicological Assessment of PFOS

For more in-depth discussion of the studies cited below, and others, refer to the MDHHS "Technical Support Document for Assessment of Perfluorinated Chemicals and Selection of a Perfluorooctane Sulfonate (PFOS) Reference Dose as the basis for Michigan Fish Consumption Screening Values (FCSVs)" (2014).

Research findings regarding the carcinogenicity of PFOS are not sufficient at this time to determine whether exposure to PFOS will increase the risk of developing cancer.

Human Epidemiology Studies

Human studies may report that a chemical exposure is *associated* with a health outcome but they rarely have the data necessary to evaluate if exposure *caused* the outcome. Because a chemical exposure may be linked to a health effect does not mean that the exposure caused that effect. Multiple lines of evidence are needed before such a conclusion can be reached.

[17] See https://www.epa.gov/pfas/and-polyfluoroalkyl-substances-pfass-what-epa-doing#tab-1 for all EPA regulatory action on perfluoroalkyl sulfonates and long-chain perfluoroalkyl carboxylate compounds.

Non-occupational health effects related to PFOS have been examined in cross-sectional studies of two large groups of people. One group is the C8 Health Project, which consists of Ohio and West Virginia residents who were exposed to PFCs, primarily PFOA, in drinking water from the Ohio River. The other group consists of participants in the National Health and Nutrition Examination Survey (NHANES), an on-going environmental chemical exposure survey of the general U.S. public. NHANES participants are selected to be representative of "the civilian, noninstitutionalized population in the United States based on age, gender, and race/ethnicity" (CDC 2009).

Although PFOA was the chemical of concern in the drinking water and therefore the main focus in the C8 study, the following are some of the findings regarding health outcomes associated with PFOS levels measured in the study participants:[18]

- Total cholesterol, low-density lipoprotein (LDL), and triglyceride levels were positively associated with PFOS levels in adults (Steenland et al. 2009).
- Total cholesterol, LDL, and high-density lipoprotein (HDL) levels were positively associated with PFOS levels in children (Frisbee et al. 2010).
- Several liver function markers, indicative of liver injury, were positively associated with PFOS levels in adults (Gallo et al. 2012).
- Higher PFOS levels were associated with children reaching puberty at a later age (Lopez-Espinosa et al. 2011).
- Total thyroxine levels (T4, a thyroid hormone) were positively associated with PFOS levels in children (Lopez-Espinosa et al. 2012).

The following are some of the health outcomes associated with PFOS levels reported in the NHANES data:

- PFOS levels in adult men (but not women) were positively associated with having currently medicated thyroid disease (Melzer et al. 2010)
- PFOS levels in children were positively associated with the risk of having Attention Deficit Hyperactivity Disorder (ADHD; Hoffman et al. 2010)

Other human populations, including groups whose diets are primarily fish, have been studied to determine correlations between PFC levels in the body and health outcomes. The following are the findings from some of these studies:

- Chateau-Degat et al. (2010) reported a positive association between PFOS and HDL levels in Inuit adults.[19]
- Yamaguchi et al. (2013) reported that PFOS levels in a group of Japanese adults were positively correlated with frequency of fish meals and levels of several liver function markers.

[18] A positive association indicates that, as PFOS levels increased, the incidence or severity of the health outcome also increased.

[19] Chateau-Degat et al. (2010) suggested that their findings might be explained by the fact that the Inuit population they studied had a diet high in omega-3 polyunsaturated fatty acids ("omega-3's"), which can increase HDL levels. Frisbee et al. (2010) reported that, in children aged 12-19 years old in the C8 study, PFOS levels were positively associated with increasing HDL levels. Neither research team theorized a reason for no finding of an HDL/PFOS association in Steenland et al. (2009).

- Andersen et al. (2010) reported that lower body weights in male infants in a Danish cohort were significantly correlated with higher maternal PFOS levels.
- Increasing odds of having asthma were positively associated with PFOS levels in Taiwanese children (Dong et al. 2013).

Note that these human studies have limited information on intake of PFOS. Additionally, the serum levels of different PFCs were found to be associated with one another in some cases, complicating the identification of health effects with an individual PFC. Therefore, these studies cannot show that PFOS, or other PFCs, cause particular human health effects but can be used to show that health effects seen in laboratory animal models can be observed in humans exposed to PFCs.

Animal Studies

Laboratory animals, such as rodents and non-human primates, frequently are used in toxicity studies of chemicals. The exposures to the animals may occur over a short-term duration, with as little as one dose, up to a chronic duration, where the animal receives the chemical for more than half its lifetime. The chemical may be administered via gavage (oral intubation), in the feed, via injection, or by other means.

A key study used in the evaluation of PFOS toxicity was conducted by Seacat et al. (2002). Male and female cynomolgus monkeys were given up to 0.75 milligrams of PFOS per kilogram body weight per day (mg/kg/day) orally for 26 weeks. The purpose of the study was to determine the earliest measurable response, and corresponding serum levels, in the treated monkeys. There were three dose groups, along with a control group. A subset of the animals was followed for one year after treatment ceased. PFOS elimination half-lives for the monkeys in this subset were about 200 days, regardless of treatment level. Blood serum PFOS levels were measured at multiple points before, during, and after treatment. Blood samples for hematology, serum chemistry, and hormonal analyses were collected at several times before and during treatment. At the end of treatment, body weights were decreased and liver effects were increased in the highest dose group. Cholesterol levels were significantly lower during the latter half of the treatment period for both sexes in the highest dose group. High-density lipoprotein (HDL) levels were significantly decreased in the low- and high-dose groups for males and in the two higher dose groups for females. Triiodothyronine (T3) levels were lower and thyroid stimulating hormone (TSH) levels higher, significantly, in both sexes in the highest dose group (Seacat et al. 2002).

The effects seen in this study are relevant to humans:

- HDL is considered the "good" form of cholesterol. If HDL levels decrease in relation to total cholesterol, a person's risk of cardiovascular disease may increase.[20]
- Reduced T3 levels may lead to hypothyroidism, which could negatively impact many of the body's systems, since the thyroid hormone is prevalent in numerous functions, such as energy metabolism, temperature regulation, and growth and development.[21]

[20] See http://www.heart.org/HEARTORG/Conditions/Cholesterol/AboutCholesterol/What-Your-Cholesterol-Levels-Mean_UCM_305562_Article.jsp.
[21] See http://www.vivo.colostate.edu/hbooks/pathphys/endocrine/thyroid/physio.html.

- An increase in TSH may indicate that the thyroid is not producing sufficient hormones (T3, the active hormone, or thyroxine [T4], which is converted to T3).

MDHHS based its chronic Reference Dose (RfD) for PFOS on the Seacat et al. (2002) monkey study. The agency selected the lowest dose in the study, 0.03 mg/kg/day, as the No Observed Adverse Effect Level (NOAEL), based on the changes in the cholesterol and thyroid hormone levels seen at higher doses. A human equivalent dose was calculated by using a physiologically-based pharmacokinetic model, resulting in a time-integrated serum concentration (the "area under the curve" [AUC]) associated with the NOAEL.[22] The AUC was adjusted for duration of the study, then converted from a monkey serum level to a human equivalent dose. This dose was then divided by uncertainty factors for interspecies and interhuman differences (values of 3 and 10, respectively). This resulted in an RfD of 0.000014 (1.4×10^{-5}) mg/kg/day (MDHHS 2014). MDHHS then developed fish consumption guidelines from the RfD (MDHHS 2015), as described briefly in the next section and in detail at www.michigan.gov/eatsafefish, under Reports and Science. Note that, in May 2016, the EPA Office of Water issued an RfD for PFOS of 0.00002 (2×10^{-5}) mg/kg/day, based on developmental effects observed in rats (EPA 2016). Using the EPA RfD would not change this report's health conclusions.

Non-primate studies have shown effects on other body systems. More research is needed to determine to what degree these effects may be applicable to human health.

- Immune system reductions in mice and rats have been identified with serum PFOS levels that are similar to levels seen in non-occupationally exposed humans (DeWitt et al. 2012). Mice appear to be more sensitive than rats to PFOS-induced immune effects (DeWitt et al. 2009), and, in some studies, male animals showed immunotoxicity at lower doses than females did (Keil et al. 2008, Peden-Adams et al. 2008, Lefebvre et al. 2008).
- Male rat pups were more sensitive than female rat pups to neurodevelopmental toxicity when born to mothers treated during gestation and postnatally with PFOS (Butenhoff et al. 2009).
- In a two-year study, rats received PFOS in the diet to assess chronic toxicity and carcinogenicity. While there were benign growths in the liver and thyroid, no cancerous growths were seen (Butenhoff et al. 2012).

Fish Consumption Guideline Determinations

The *Michigan Fish Consumption Advisory Program (MFCAP) Guidance Document* (MDHHS 2015) describes how fish consumption guidelines are determined. The MFCAP relies on the analysis of fish tissue collected from a given waterbody to develop and adjust fish consumption guidelines. Edible portions, typically fish filets, are analyzed for contaminants, and the fish consumption guideline is set to be protective of all detected chemicals. The MFCAP uses Fish Consumption Screening Values (FCSVs) to inform the determination of fish consumption guidelines. Table 2, shown earlier in this document, lists the PFOS FCSVs. The FCSVs for PFOS and other chemicals can be found in the MFCAP Guidance Document.

In addition to FCSVs, MDHHS uses information about the contaminant source and how concentrations in the fish population change over time to inform guideline determination. When

[22] The AUC was used by the MDEQ Water Resources Division for derivation of its Rule 57 Human Noncancer Value for PFOS (MDEQ 2014).

waterbodies are impacted by uncontrolled chemical inputs from a known source, the variability of fish tissue data sets can increase. Therefore, MDHHS requires more samples than the standard data goal described in the guidance document in order to characterize the increased variability. PFOS is a new chemical in the MFCAP with limited information on concentration differences between species within a waterbody. Until sufficient information is obtained, MDHHS will use management decisions to protect public health, as described in the MFCAP Guidance Document.

PFOS-contaminated groundwater has been documented to be entering Clark's Marsh ponds, the lower Au Sable River, and other waterbodies near WAFB (Appendix A). As seen in the available fish tissue data, PFOS can reach concentrations that result in Do Not Eat fish consumption guidelines. MDHHS determined that the lack of PFOS source characterization at WAFB, continued PFOS entry into local waters, and elevated PFOS filet concentrations required an advisory of Do Not Eat for all species of fish from Clark's Marsh Ponds and resident fish from the lower Au Sable River. The Au Sable River advisories will be updated when sufficient fish filet analytical data are obtained. In addition, a Do Not Eat waterbody-wide advisory was placed on Allen Lake due to its proximity to the fire training area (FT-2) and a surface water sample from a stream draining the lake having detectable PFOS levels (Appendix A).

As stated earlier, the EPA Office of Water has derived an RfD for PFOS. The ATSDR (2015) has released a Draft for Public Comment Toxicological Profile for Perfluoroalkyls and proposed, but has not finalized, Minimal Risk Levels (MRLs). As EPA and ATSDR update comparison values for PFOS, MDHHS will review and, as necessary, update the PFOS Technical Support Document to ensure that the guidelines remain protective.

Children's Health Considerations

Studies in laboratory animals have shown long-chain PFCs, such as PFOS, have developmental toxicity, which makes exposure a concern to children's health. Several of the animal studies discussed in the MDHHS Technical Support Document (2014) discuss effects in offspring.

Beesoon et al. (2011) compared human maternal and umbilical sera and concluded that, although longer chain PFCs had lower transplacental transfer efficiencies, there was still delivery of PFOS and other PFCs from the mother to the fetus. Pregnant women eating PFOS-contaminated fish from waterbodies near WAFB may expose the developing fetus.

Exposure to newborn and older babies could occur through the mother's breast milk. Barbarossa et al. (2013) measured PFOS and PFOA in human breast milk and found the chemicals in more than three quarters of the samples for those mothers breastfeeding for the first time and in about half of the samples for those mothers in their second or later lactation. Nursing mothers eating PFOS-contaminated fish from waterbodies near WAFB may expose the breastfed infant.

Due to PFOS's long half-life in humans (5.4 years [Olsen et al. 2007]), children could be accumulating PFOS during major developmental periods. This may result in a greater chance of children developing health effects from long-term PFOS exposure. In addition, infants may have a reduced capacity to eliminate PFOS, due to still developing organ systems (ATSDR 2015).

Community Health Concerns

Local officials and community members have asked whether the Do Not Eat guidelines pertain to all fish species or only certain ones. The Do Not Eat guidelines pertain to all fish in the Clark's Marsh ponds and Allen Lake but only to resident fish in the lower Au Sable River (those fish living in the river year-round). Migratory fish in the river (walleye, rainbow trout/steelhead, and salmon) are covered by Eat Safe Fish guidelines for Lake Huron. Fish from area waterbodies may have waterbody-specific guidelines due to other chemicals or are covered by the Statewide Safe Fish Guidelines (for when a waterbody or fish species is not listed). "Eat Safe Fish" guides, showing the fish-consumption guidelines, are available at www.michigan.gov/eatsafefish.

Some of the public have suggested there are not enough fish tissue data to warrant the Do Not Eat fish consumption advisory. The concentrations of PFOS found in fish sampled from Clark's Marsh were higher than those found in other states with PFC contamination in fish and were up to 30 times greater than Michigan screening values. Furthermore, the source of contamination is not yet under control. Recommending that no one eat those fish is good public health practice. More data are being gathered and the USAF is addressing the contamination. Fish consumption guidelines will be relaxed when concentrations are determined to be safe for human consumption.

Appendix E lists other concerns expressed by the community but not related to fish consumption.

Conclusions

MDHHS has reached the following conclusion about the PFOS contamination at and near WAFB:

Levels of PFOS found in fish consumed regularly from Clark's Marsh, Allen Lake, and portions of the Au Sable River could harm people's health.

Basis: There are multiple locations at WAFB with PFC contamination, particularly at the FT-02 fire-training area. Some of this contamination has impacted fish in local waterbodies. The primary PFC of concern in the fish is PFOS, with fish tissue concentrations exceeding MDHHS screening values, including Do Not Eat levels.

Recommendations

1. Determine if and to what extent other areas of PFC contamination at WAFB are impacting local waterbodies, including the lower Au Sable River and Van Etten Lake.
2. Control off-site migration of PFCs from other source areas at WAFB.
3. Obtain more fish PFC data for the area, to establish a baseline for comparison to data obtained after remediation.
4. Obtain PFC data on filets of fish that are likely to be consumed from the lower Au Sable River, Van Etten Lake, and Allen Lake to support updated Eat Safe Fish guidelines.
5. Provide the public with information regarding safe fish choices from waterbodies near WAFB.

Public Health Action Plan

1. The USAF, with MDEQ oversight, is continuing environmental investigations at WAFB. In 2015, MDEQ discovered PFCs in drinking water wells near WAFB. MDHHS has made recommendations to affected well owners to use an alternate water source for drinking and cooking.[23]
2. The USAF has installed a pump-and-treat system near FT-02 to remediate PFC-contaminated groundwater in that area. The system became operational in April 2015.
3. The USAF will collect more fish to establish a pre-remediation baseline and fill data gaps in the Eat Safe Fish Guidelines and will confer with MDHHS regarding future fish sampling. MDEQ may choose to sample fish in the area at any time, to monitor for PFCs or other contaminants (e.g., mercury, polychlorinated biphenyls [PCBs]).
4. MDHHS has provided signs and brochures specific to the area. Signs were posted at Clark's Marsh and Allen Lake in 2013 and along the lower Au Sable River in 2013 and 2014. Brochures were distributed locally and posted to MDHHS's website in 2014 and 2015.

MDHHS will remain available as needed for future consultation at this site.

If any citizen has additional information or health concerns regarding this health consultation, please contact MDHHS's Division of Environmental Health at 1-800-648-6942.

[23] See www.michigan.gov/wurtsmith for more information.

Report Preparation

This Health Consultation for the former Wurtsmith Air Force Base, regarding contamination of local fish, was prepared by the Michigan Department of Health and Human Services (MDHHS) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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Appendix A. Perfluorinated chemicals at and near the former Wurtsmith Air Force Base, Oscoda (Iosco County), Michigan - water sampling results

The following perfluorinated chemicals (PFCs) were analyzed for in groundwater and surface water samples taken at and near the former Wurtsmith Air Force Base (WAFB) in Oscoda, Michigan (those in bold were detected):[24]

Perfluorobutane sulfonate (PFBS)	**Perfluorononanoic acid (PFNA)**
Perfluorobutanoic acid (PFBA)	Perfluorooctandecanoic acid (PFODA)
Perfluorodecane sulfonate (PFDS)	**Perfluorooctane sulfonamide (PFOSA)**
Perfluorodecanoic acid (PFDA)	**Perfluorooctane sulfonate (PFOS)**
Perfluorododecanoic acid (PFDoA)	**Perfluorooctanesulfonamidoacetic acid (FOSAA)**
Perfluoroheptane sulfonate (PFHpS)	**Perfluorooctanoic acid (PFOA)**
Perfluoroheptanoic acid (PFHpA)	**Perfluoropentanoic acid (PFPA)**
Perfluorohexadecanoic acid (PFHxDA)	Perfluorotetradecanoic acid (PFTeA)
Perfluorohexane sulfonate (PFHxS)	Perfluorotridecanoic acid (PFTriA)
Perfluorohexanoic acid (PFHxA)	**Perfluoroundecanoic acid (PFUnA)**

Figure A-1 shows the WAFB Installation Restoration Program (IRP) sites where sampling activities have occurred. Figures A-2, A-3, and A-4 show areas noted in Figure A-1.

Table A-1 shows the PFOS concentrations in groundwater samples. The Michigan Department of Environmental Quality (MDEQ) or the U.S. Air Force (USAF) conducted the sampling between 2010 and 2012. If a well was sampled more than once in that timeframe, only the most recent results are included in the table. For duplicate samples, only the higher result is included. Not all of the groundwater samples had the full suite of chemicals analyzed; initially, only PFOS and PFOA were investigated. When the full suite of chemicals was analyzed for, the PFC with the highest concentration was not always PFOS; other PFCs with the highest concentration in a sample were PFBA, PFHxA, PFHxS, PFOA, or PFPeA. The inconsistency in the PFC profile may be due to different formulations of fire-fighting foams, to the release of other PFC-containing materials, or to the contribution of polyfluorinated telomer breakdown products to the contaminant load.

[24] The analysis of PFCs in water samples allows for the identification of more chemicals than in soil, sediment, or biota samples. Therefore, there are more PFCs listed above as compared to in the *Environmental Contamination* section of this document, where PFCs in fish are discussed.

Figure A- 1. Installation Restoration Program (IRP) sites at the former Wurtsmith Air Force Base, Oscoda (Iosco County), Michigan (MWH 2013).

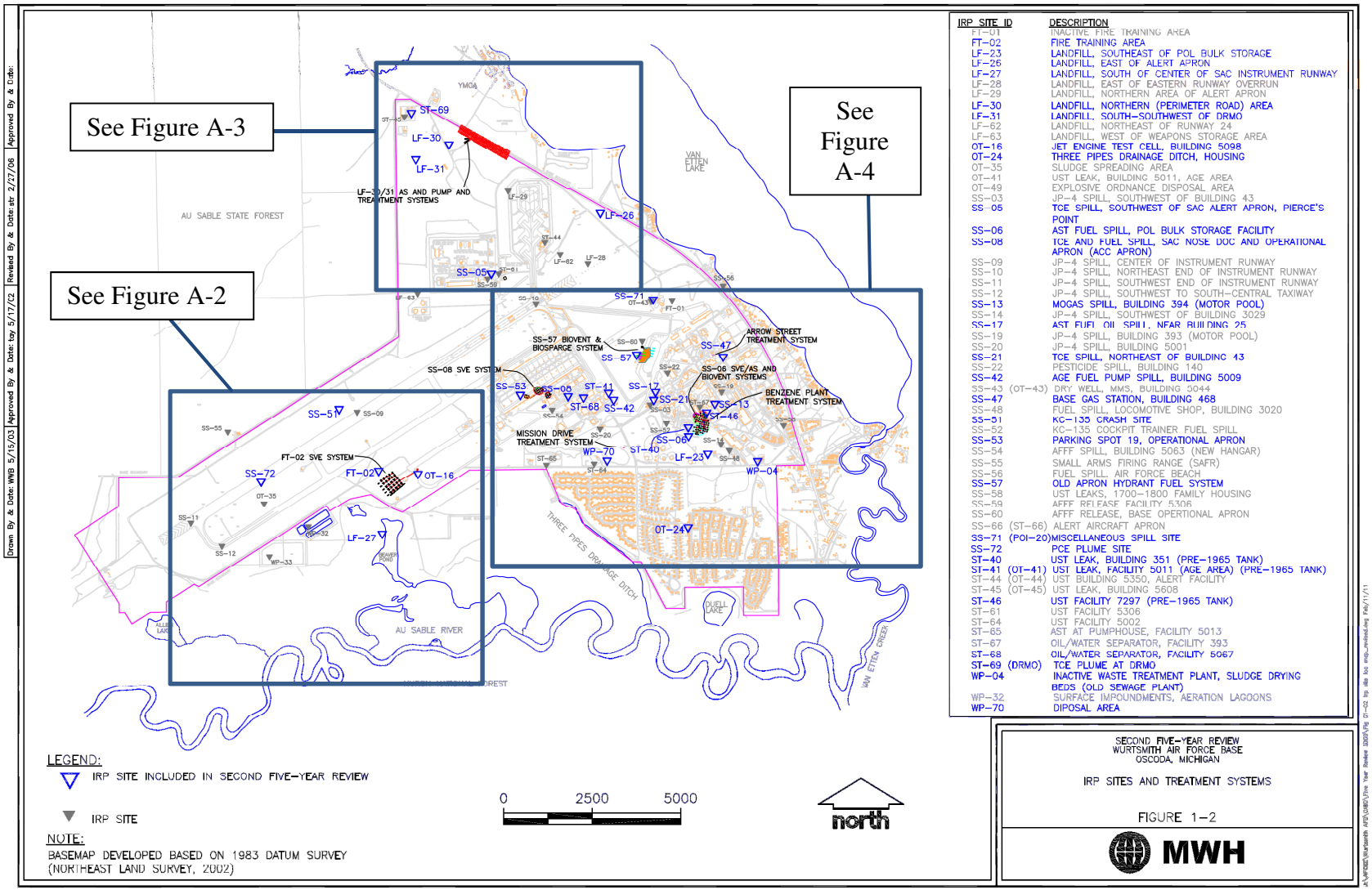

Figure A- 2. West section of Wurtsmith Air Force Base map in Figure A-1, including the fire-training site (FT-02).

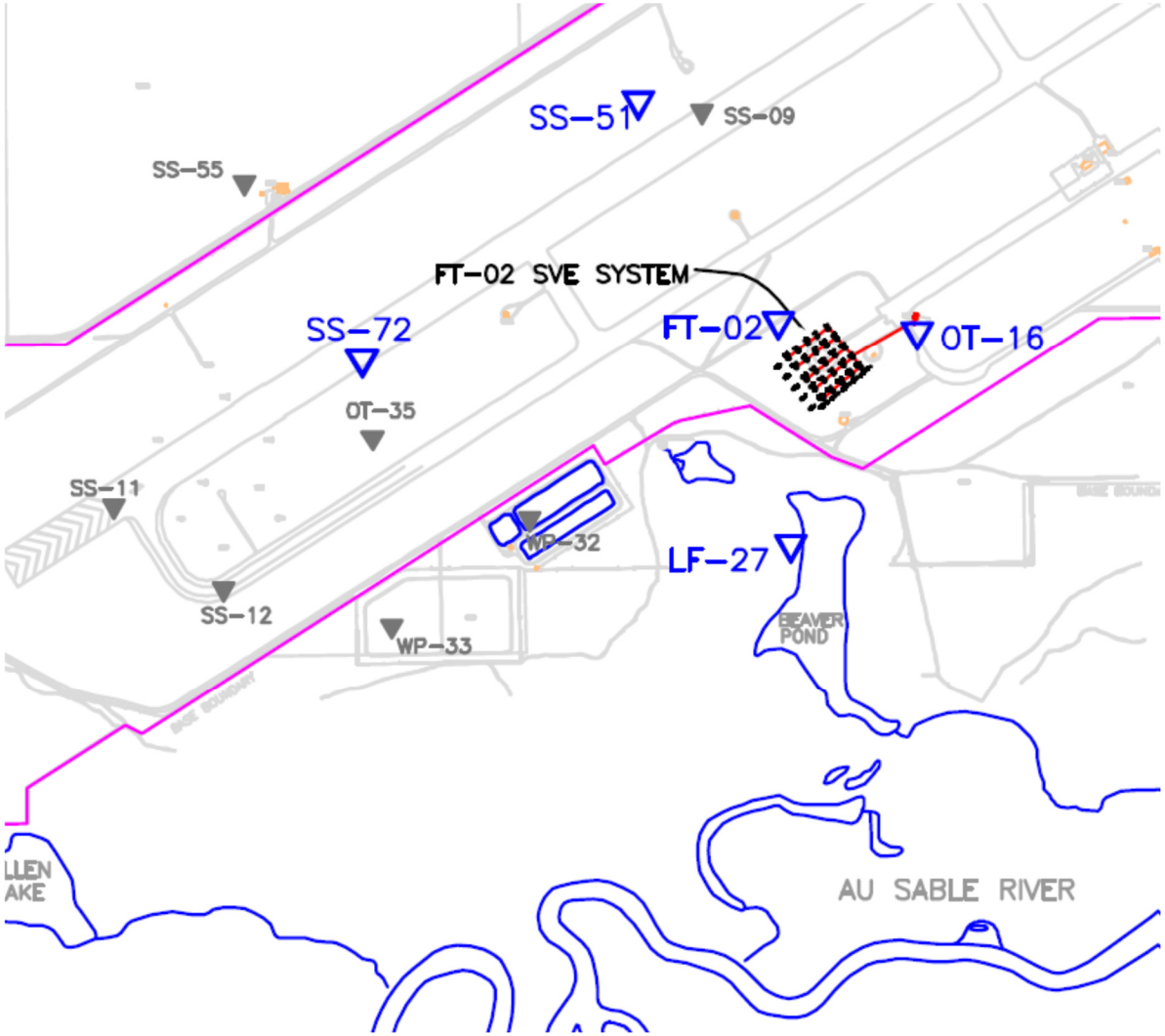

Figure A- 3. North section of Wurtsmith Air Force Base map in Figure A-1.

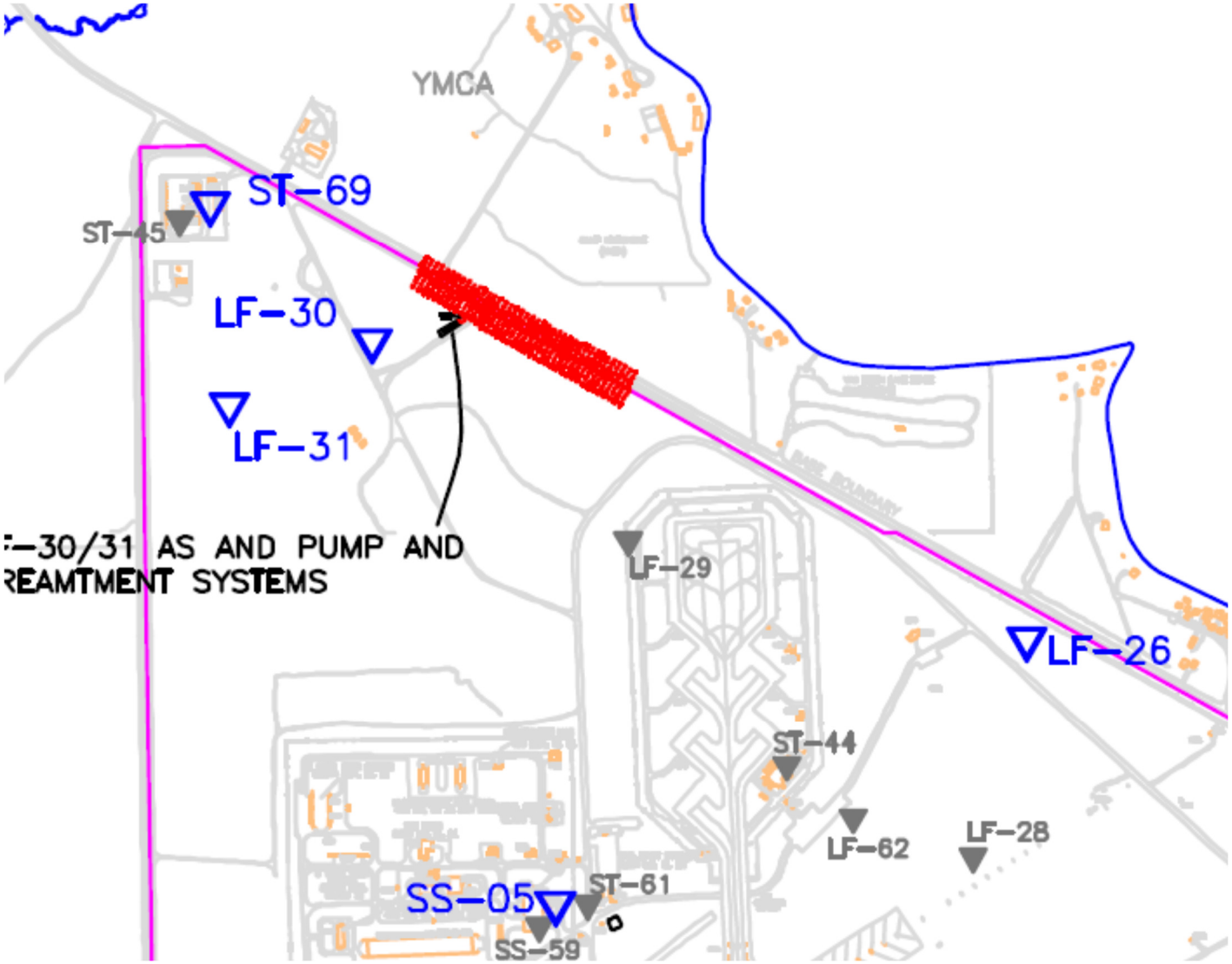

Figure A- 4. East section of Wurtsmith Air Force Base map in Figure A-1.

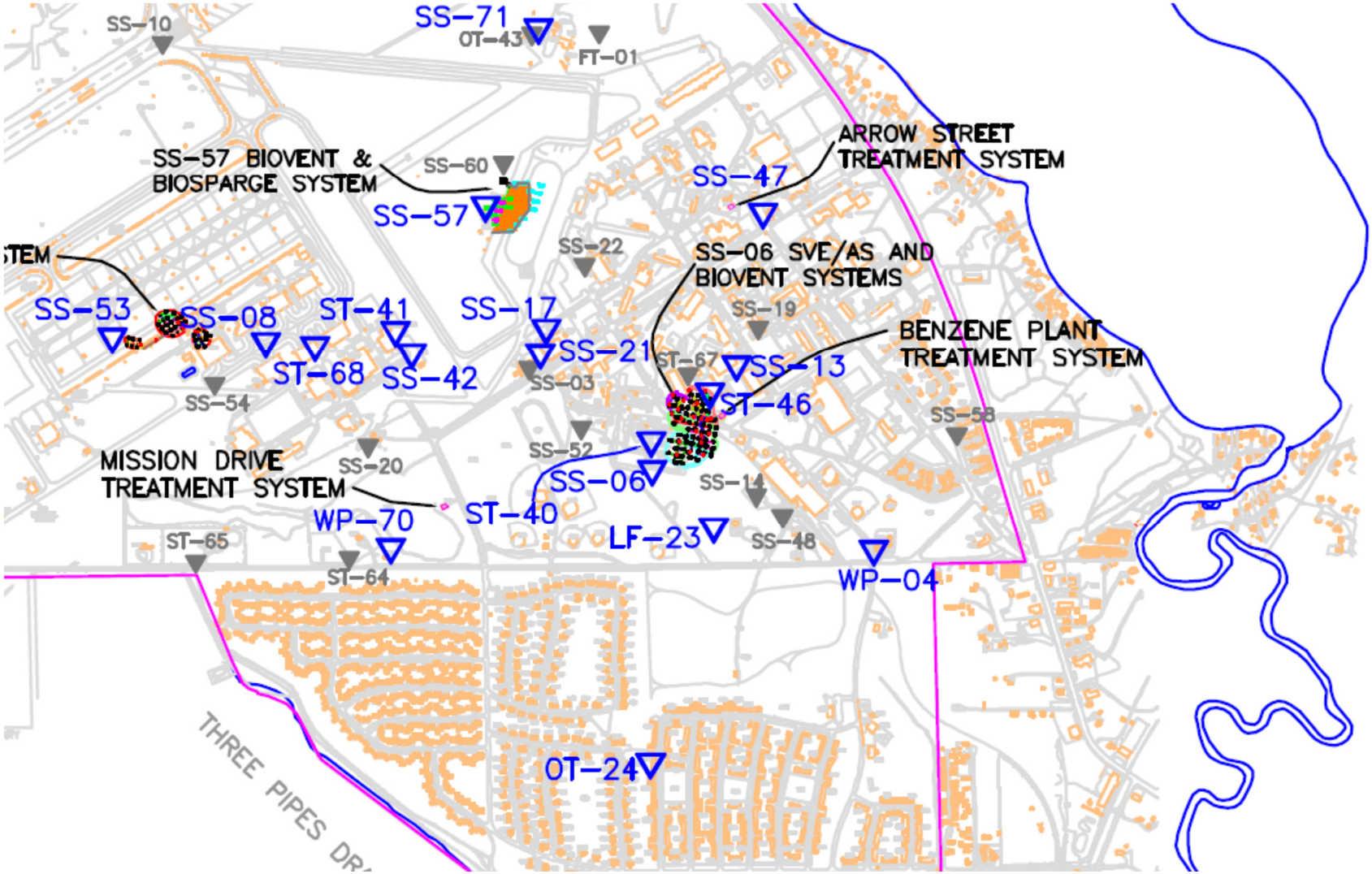

Table A- 1. Perfluorooctane sulfonate (PFOS) concentrations (in parts per trillion [ppt]) in groundwater samples at or near the former Wurtsmith Air Force Base (WAFB) in Oscoda, Michigan.

Groundwater Monitoring Locations	No. detects / No. wells sampled	Concentration Range (ppt)
Background (state forest northwest of base)	1 / 11	ND - 5
See Figure A-2		
FT-02	33 / 33	59 – 600,000
LF-27	7 / 13	ND – 680
OT-16	4 / 5	ND – 7,500
SS-09	1 / 1	12
SS-51	4 / 4	87 – 2,400
SS-72	0 / 3	ND
WP-32/33	1	2,600
See Figure A-3		
LF-30/31	9 / 10	ND – 37
OT-45 (shown as ST-45)	1 / 1	190
SS-05	0 / 3	ND
ST-69	3 / 3	51 – 970
See Figure A-4		
OT-24	0 / 7	ND
SS-06	1 / 2	ND – 3.6
SS-08	7 / 7	32 – 15,000
SS-21	3 / 6	ND – 260
SS-42	2 / 2	150 – 2,400
SS-53	1 / 1	110
SS-57	4 / 4	720 – 20,000
SS-71	2 / 2	84 – 680
ST-40	1 / 1	350
ST-46	3 / 3	490 – 3,500
WP-04	3 / 4	ND - 16

"ND" means not detected. Reporting Limit ranged from 1.2 to 4.2 ppt.

Table A-2 shows the PFOS concentrations in surface water samples at or near WAFB. Sampling was conducted by MDEQ or the USAF between 2010 and 2014. If a location was sampled more than once in that timeframe, only the most recent results are included in the table. For duplicate samples, only the higher result is included. For all the samples, either PFHxS or PFOS was the PFC with the highest concentration.

Table A- 2. Perfluorooctane sulfonate (PFOS) concentrations (in parts per trillion [ppt]) in surface water samples at or near the former Wurtsmith Air Force Base (WAFB), in Oscoda, Michigan.

Surface Water Sample Locations	**No. detects / No. samples**	**Concentration Range (ppt)**
Clark's Marsh waterbodies (upper, middle, and lower ponds; west inlet; north outlet)	10 / 10	210 - 7,400
FT-02 (seeps near upper pond in Clark's Marsh)	5 / 5	65 - 19,000
LF-27	1 / 1	660
Lower Au Sable River and connecting waterways (Rea Road access, River Road access, Van Etten Creek at Highway F41, 3 Pipes outfalls, Consumers outfall, five unnamed streams)	14 / 15	ND – 4,600
Tuttle Marsh (about four miles south of lower Au Sable River/Foote Dam)	0 / 1	ND
Pine River (enters Van Etten Lake at north end)	0 / 1	ND
Van Etten Lake (including seeps at Camp Nissokone)	4 / 6	ND - 34.3

"ND" means not detected. Reporting Limit ranged from 1.9 to 2 ppt.

Appendix B: "Eat Safe Fish" signs installed in 2013 and 2014 next to various waterbodies near the former Wurtsmith Air Force Base in Oscoda (Iosco County), Michigan.

Figure B- 1. Sign installed by Clark's Marsh ponds (Iosco County, Michigan) in 2013.

Figure B- 2. Sign installed by Allen Lake (Iosco County, Michigan) in 2013.

Figure B- 3. Sign installed at various locations along the lower Au Sable River (Iosco County, Michigan) in 2013.

Do not eat certain fish from the Au Sable River - Foote Dam to Lake Huron

There are high amounts of perfluorinated chemicals (PFCs) in fish that live in this part of the river year round. Eating them could harm your health.

Michigan Department of Community Health

MDCH

<u>Do not eat</u> resident river fish such as sunfish, bass, and perch.

Migratory lake fish such as salmon and steelhead do not have high levels of PFCs.

Catch and release fishing, boating, and swimming are fine. Touching the water will not harm you.

MDCH has meal guidelines for some Au Sable River and Lake Huron fish because of other chemicals. Call MDCH at 1-800-648-6942 or visit www.michigan.gov/eatsafefish.

Or scan this with your smartphone.

Figure B- 4. Revised sign installed at various locations along the lower Au Sable River (Iosco County, Michigan) in 2014. (Gap in title line indicates where upper bolt for attaching the sign is placed.)

Appendix C. Perfluorooctane Sulfonate (PFOS) Fish Contaminant Screening Level (FCSV) Worksheet (extracted from the 2015 Michigan Fish Consumption Advisory Program Guidance Document)[25]

Chemical Name: Perfluorooctane Sulfonate (PFOS)
CAS Number: 1763-23-1
FCSV Health Basis: Non-cancer
Interim Reference Dose (RfD): 0.014 micrograms per kilogram per day (µg/kg-day)
Relative Source Contribution (RSC) = 1

State of Michigan
Fish Consumption Screening Value Ranges for PFOS

Meal Category	**FCSV Ranges**	
meals per month[a]	*µg/g (ppm)*[b]	*ng/g (ppb)*[c]
16	≤ 0.009	≤ 9
12	>0.009 to 0.013	>9 to 13
8	>0.013 to 0.019	>13 to 19
4	>0.019 to 0.038	>19 to 38
2	>0.038 to 0.075	>38 to 75
1	>0.075 to 0.15	>75 to 150
6 meals per year	>0.15 to 0.3	>150 to 300
Do Not Eat	>0.3	>300

[a] Units are in months unless otherwise stated.
[b] micrograms of chemical per gram of wet weight fish tissue (µg/g) that is the same as parts per million (ppm).
[c] nanograms of chemicals per grams of wet weight fish tissue (ng/g) that is the same as parts per billion (ppb)

Limited Meal Category
No *Limited* meal category is provided for the PFOS screening values due to the still emerging information on health effects from PFOS exposure, the background exposure in the general population (to PFOS and other perfluorinated chemicals [PFCs]), and potential health effects from exposure to multiple PFCs.

Do Not Eat Meal Category
Fish in the *Do Not Eat* meal category were found to contain high levels of PFOS. Michigan Department of Health and Human Services (MDHHS) recommends that no one ever eat the fish in this category.

[25] See www.michigan.gov/eatsafefish, under "Reports and Science." Methodology and equations for developing FCSVs are contained in Appendix A of the guidance document.

Toxicological Assessment

MDHHS evaluated the literature on PFOS toxicology and epidemiology for both cancer and non-cancer risk, and set an interim RfD. The MDHHS interim RfD is described in the health consultation entitled Technical *Support Document for Assessment of Perfluorinated Chemicals and Selection of a Perfluorooctane Sulfonate (PFOS) Reference Dose as the basis for Michigan Fish Consumption Screening Values (FCSVs)* (MDCH 2014) provided at www.michigan.gov/eatsafefish under *Reports & Science.* The interim RfD is briefly described below.

MDHHS selected a no-observed-adverse-effect level (NOAEL) of 0.03 milligrams per kilogram per day (mg/kg-d) from a sub-chronic monkey study (N=44 monkeys). Health effects identified in the treated monkeys included reduced cholesterol and thyroid hormone levels (Seacat et al. 2002).

Physiologically-based pharmacokinetic modeling was used to determine a time-integrated serum concentration, also known as an area under the curve (AUC), associated with the NOAEL. The Michigan Department of Environmental Quality Water Resources Division used the AUC of 22,100 milligrams/Liter*hour in their derivation of a Rule 57 Human Noncancer Value for PFOS (MDEQ 2014). The AUC, adjusted for duration of the study (182 days [d]), resulted in an average serum concentration (5.06 mg/L) at steady-state. The average serum concentration can be converted to a human equivalent dose at steady-state using information on PFOS clearance in humans. The human equivalent dose ($4.1x10^{-4}$ mg/kg/d) associated with the NOAEL was divided by a total uncertainty factor of 30 (10 for human-to-human variability and 3 for animal-to-human toxicodynamic variability not accounted for in the human equivalent dose calculation), resulting in the MDHHS interim RfD of 1.4×10^{-5} mg/kg/d.

Although the US EPA has released a draft health effect assessment for PFOS, no RfD has been finalized as yet. MDHHS will continue to follow the progress of that assessment and re-evaluate the interim RfD when the U.S. EPA issues a final value.

Cancer Risk Considerations

No studies of humans exposed orally to PFOS were identified in the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicology Profile (ATSDR 2009). Animal studies provided inconclusive results regarding PFOS carcinogenicity (ATSDR 2009). Some animal studies reported DNA damage that was likely due to reactive oxygen species (ATSDR 2009). PFOS was found to be non-mutagenic in bacteria, human lymphocytes, or rat hepatocytes (ATSDR 2009). MDHHS has not identified a cancer slope factor for PFOS.

Vulnerable (Sensitive) Population Considerations

Human fetuses are exposed during development to PFOS from contaminated fish that the mother eats. Exposure to newborn and older babies could occur through the mother's breast milk. In addition, infants may have a reduced capacity to eliminate PFOS, due to still developing organ systems. Literature describing associations between PFOS exposure and effects in children is limited (ATSDR 2009). Studies of rodents exposed to PFOS have shown development effects (ATSDR 2009).

References

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Appendix D. Perfluorooctane sulfonate (PFOS) concentrations detected in filet tissue of fish sampled near the former Wurtsmith Air Force Base. Concentrations given in parts per billion (ppb).

Waterbody	Note	Species	Collection Year*	No. detected / No. samples	PFOS Range
Clark's Marsh - Upper Pond	A	Largemouth Bass	2012	4 / 4	3,110 - 8,720
	B	Pumpkinseed	2011	14 / 14	3,170 - 9,580
	A	Pumpkinseed	2012	5 / 5	1,990 – 4,760
	A	Yellow Perch	2012	2 / 2	2,750 - 2,930
Clark's Marsh - Middle Pond	A	Pumpkinseed	2012	4 / 4	2,760 - 4,500
	A	Yellow Perch	2012	1 / 1	1,770
Clark's Marsh - Lower Pond	B	Bluegill	2011	1 / 1	1,290
	A	Largemouth Bass	2012	4 / 4	683 - 1,100
	B	Pumpkinseed	2011	4 / 4	334 - 548
	A	Pumpkinseed	2012	3 / 3	551 - 828
Allen Lake	B	Largemouth Bass	2012	1 / 1	2
Lower Au Sable River	B	Bluegill	2012	1 / 1	41
	B	Pumpkinseed	2012	3 / 3	35 - 2,956
	B,C	Rainbow Trout	2013	10 / 10	7 - 28
	B	Rock Bass	2012	8 / 8	7 - 49
	B,D	Smallmouth Bass	2011, 2012	20 / 20	14 - 424
	B,C	Walleye	2013	7 / 7	10 - 30
	B	White Sucker	2011	10 / 10	6 - 143
Van Etten Lake	B	Pumpkinseed	2012	10 / 10	6 - 13
	B	Rock Bass	2012	10 / 10	5 - 18
	B	Walleye	2010	10 / 10	4 - 46
	B	White Sucker	2010	10 / 10	1 - 28
	A	Yellow Perch	2012	2 / 2	6 - 13
Tuttle Marsh	A	Pumpkinseed	2012	1 / 4	1
Northern and central Lake Huron (between Upper Peninsula and tip of Michigan's "thumb")[D]	E	Brown Trout	2010	1 / 1	49
	E	Channel Catfish	2010	1 / 1	73
	E	Freshwater Drum	2010	3 / 3	13 - 25
	E	Lake Trout	2010	17 / 17	3 - 43
	E	Lake Whitefish	2010	1 / 1	7
	E	Rainbow Trout	2010	4 / 4	4 - 23
	E	Smallmouth Bass	2010	1 / 1	17
	E	Walleye	2010	1 / 1	23
*These data cannot be used for determining temporal trends of PFOS concentrations in the fish.					

Notes:

[A]These fish were collected by the Michigan Department of Environmental Quality (MDEQ) as part of that agency's investigative work and are *not* part of the Michigan Department of Health and Human Services (MDHHS) Michigan Fish Consumption Advisory Program (MFCAP) database because the results have not been validated by the MDHHS Analytical Chemistry Laboratory.

[B]These fish were collected by the MDEQ and *are* part of the MFCAP database, which means the data have been validated by the MDHHS Analytical Chemistry Laboratory. .

[C]These fish, while caught from the lower Au Sable River, are known to migrate between Lake Huron and the Au Sable River. Therefore, they are considered Lake Huron migratory fish in the MFCAP Eat Safe Fish guides.

[D]Five of these fish were less than legal-limit size and not used to establish a fish consumption guideline.

[E]These fish were collected by the U.S. Environmental Protection Agency and are *not* part of the MFCAP database because the results have not been validated by the MDHHS Analytical Chemistry Laboratory.

Appendix E. Community health concerns pertaining to potential perfluorinated chemical exposures, other than fish consumption, near the former Wurtsmith Air Force Base in Oscoda (Iosco County), Michigan.

Note that many of these concerns have been addressed in Michigan Department of Health and Human Services (MDHHS) fact sheets and may be addressed in more detail in subsequent documents.

People have reportedly asked whether body contact with perfluorooctane sulfonate (PFOS)-impacted waterbodies is a health concern. People may have contact with the water when swimming, wading, boating, or fishing. The chemistry of PFOS suggests that it is not likely to absorb through the skin. The occasional swallow of water that may occur when recreating is not likely to be enough exposure to cause health effects. Therefore, contact with area waterbodies is not a concern with regard to PFOS.

People have reportedly asked whether dogs drinking from perfluorinated chemical (PFC)-impacted waterbodies may be harmed by the contamination. MDHHS presumes that pets and domestic animals (such as horses) would receive their drinking water from private wells or municipal supplies and not from area waterbodies. No harm would be expected, with regard to PFCs, if someone's animal occasionally drinks from area waterbodies. There can be other water quality issues, such as algal blooms in lakes and ponds, which might harm an animal's health.

Local birding groups have asked to what extent birds using the area may be impacted. The area gets heavy use by birders and duck hunters (MDEQ 2006a). Birds that eat area fish are more likely to have higher amounts of PFOS in their bodies than those that eat insects, seeds or other vegetation. Migratory birds are likely to be less impacted by the contamination than birds using the ponds year-round. The U.S. Geological Survey conducted a study on swallows (which eat insects) nesting in and near Clark's Marsh in 2014, to determine impacts on songbirds. Analytical results of bird plasma, eggs, and crop contents showed elevated levels of various PFCs, including PFOS. This suggests the uptake of PFCs in terrestrial animals near the former Wurtsmith Air Force Base (WAFB; R. Delaney, MDEQ, personal communication, 2013).

Similarly, there are concerns that area game species may be impacted by the PFC contamination. Area game animals and waterfowl have not been tested yet for PFCs. Other persistent and bioaccumulative environmental chemicals have been detected in game species in Michigan (MDHHS 2005). MDHHS is evaluating the need for sampling wild game near WAFB and discussing this matter with other agencies.

It is possible that local residents will use groundwater from potentially contaminated, unabandoned wells to water their vegetable gardens. The Minnesota Department of Health (MDH) conducted a study to determine if garden produce could accumulate PFCs in this manner. The study considered seven PFCs, including PFOS, detected in drinking water used for irrigation and/or in garden soil samples. Based on the results of the study, MDH concluded that PFOS was not readily bioavailable to the edible parts of plants (MDH 2012). Therefore, it is unlikely that people would have significant exposure when consuming produce irrigated with water potentially contaminated with PFOS near WAFB.

Following the May 2012 release of the Do Not Eat fish advisory, the USAF conducted screening for PFCs at Camp Nissokone, a Young Men's Christian Association (YMCA) camp east of WAFB on the west shore of Van Etten Lake (Figure 2; data not shown). (The camp is down-gradient from WAFB's municipal landfill and the USAF has an ongoing monitoring program on the campground.) Surface water, sediment, and soil samples were collected on the camp property. Wipe samples were collected from one of the cabins and the dining hall. The samples were analyzed for PFCs. PFOS was not detected in any of the samples, however three other PFCs were detected in several samples at very low levels. All three surface water samples had perfluorohexane sulfonate (PFHxS, estimated concentrations of 13, 14, and 16 parts per trillion [ppt]) and one had an estimated 3.2 ppt perfluorohexanoic acid (PFHxA).[26] Two soil samples taken from the driveway had detections of perfluoropentanoic acid (PFPA; concentrations of 1.7 and 2.1 ppb). The source of these PFCs has not been determined.

A member of the Chippewa Nation of the Great Lakes attended the January 2013 community meeting in Oscoda and mentioned that the tribe holds its powwow near the Au Sable River. In the past, the Gagaguwon Powwow was held annually at Old Orchard Park, just upstream of Foote Dam. According to Michigan Department of Environmental Quality (MDEQ), the contamination from WAFB appears to be entering the Au Sable River downstream of the dam. Therefore, the upper river is not expected to be impacted by contamination from WAFB. The tribe does not report using the lower Au Sable River for fish harvesting.

The state legislator representing Michigan District 106, which includes the Oscoda area, requested a meeting with MDHHS in March 2013 so that he could understand the contamination and public health issues. As a result of the meeting, he asked MDHHS to provide language for a press release that he would issue on his website, as another means of communication with concerned constituents.[27]

[26] The laboratory estimated the concentrations because, while the PFCs were positively identified, the concentrations were so low that they were out of the calibration range of the analytical instrument.
[27] The news release is available at http://gophouse.org/foote-dam-fish-consumption-guidelines-continue/.